ECOLOGICAL EVALUATION OF PROPOSED OCEANIC DISCHARGE OF DREDGED MATERIAL FROM TAUNTON RIVER AND MOUNT HOPE BAY, MASSACHUSETTS AND RHODE ISLAND

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As judged by the toxicity-related criteria employed in this report, oceanic discharge of dredged material from the Taunton River and Mount Hope Bay to a disposal site near Brenton Reef is ecologically acceptable. Copepods, mysid shrimp, and Atlantic silversides were placed in 100% liquid and suspended particulate phases of dredged material for 96 hours. The survival of these organisms was not significantly lower than the survival of the same organisms exposed for the same amount of time to a culture water control.

Hard clams, grass shrimp, and sandworms that survived from the solid phase of dredged material usually did not contain significantly elevated concentrations of xenobiotic constituents in their tissues as compared to tissues of reference organisms. However, hard clams exposed to dredged material from Reach C of the study area exhibited a statistically important uptake of petroleum hydrocarbons.

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SUMMARY

The proposed oceanic discharge of dredged material from the Taunton River and Mount Hope Bay, Massachusetts and Rhode Island, to a disposal site near Brenton Reef is ecologically acceptable as judged by the toxicity-related criteria employed in this evaluation. In most cases, survival of copepods (Acartia tonsa), mysid shrimp (Neomysis americana), and Atlantic silversides (Menidia menidia) exposed for 96 hr to 100% liquid and suspended particulate phases of dredged material was not significantly lower ($\alpha = 0.05$) than survival of the same organisms exposed for 96 hr to a culture water control. In the one case in which survival of organisms exposed for 96 hr to 100% dredged material was significantly lower than control survival - i.e., copepods exposed to the liquid phase of dredged material - the limiting permissible concentration for the phase is greater than the environmental concentration of the phase at the end of initial mixing (the 4-hr period immediately following dumping of the dredged material), and it appears that this relationship is maintained indefinitely. In addition, total (combined) survival of grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) exposed for 10 days to the solid phase of dredged material was not significantly lower than survival of reference organisms.

Tissues of grass shrimp, hard clams, and sandworms that survived exposure to the solid phase of dredged material usually did not contain significantly elevated ($\alpha = 0.05$) concentrations of xenobiotic constituents (cadmium, mercury, polychlorinated biphenyls, the dichloro-diphenyl-trichloroethane family, and petroleum hydrocarbons) as compared to tissues of reference organisms. However, hard clams exposed to dredged material from Reach C of the study area exhibited a statistically important ($\alpha = 0.05$) uptake of petroleum hydrocarbons.

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1. INTRODUCTION

The objective of this evaluation is to assess the ecological acceptability of the proposed oceanic discharge of dredged material from the Taunton River and Mount Hope Bay, Massachusetts and Rhode Island (Figure 1), to a disposal site located near Brenton Reef. If the proposed discharge is judged to be ecologically acceptable according to the bioassay- and bioaccumulation-related criteria employed in the evaluation, the disposal practice is considered to be in partial compliance with Subpart B (Environmental Impact) of the ocean dumping regulations (U.S. EPA, 1977).

Subpart B (Environmental Impact) of the ocean dumping regulations consists of the following basic sections: §227.5 (Prohibited Materials); §227.6 (Constituents Prohibited as Other than Trace Contaminants); §227.7 (Limits Established for Specific Wastes or Waste Constituents); §227.8 (Limitations on the Disposal Rates of Toxic Wastes); §227.9 (Limitations on Quantities of Waste Materials); §227.10 (Hazards to Fishing, Navigation, Shorelines or Beaches); §227.11 (Containerized Wastes); §227.12 (Insoluble Wastes); and §227.13 (Dredged Materials). Disposal of dredged material must comply with restrictions and limitations imposed by §227.5, §227.6, §227.9, §227.10, and §227.13 of the regulations (U.S. EPA, 1977).

Dredged material from the study area complies with §227.5 (Prohibited Materials) of the ocean dumping regulations since it does not contain high-level radioactive wastes; materials used for warfare; insufficiently described materials; or persistent, inert substances that may interfere materially with legitimate uses of the ocean. Compliance of the material with toxicological (bioassay-based) and bioaccumulation-related

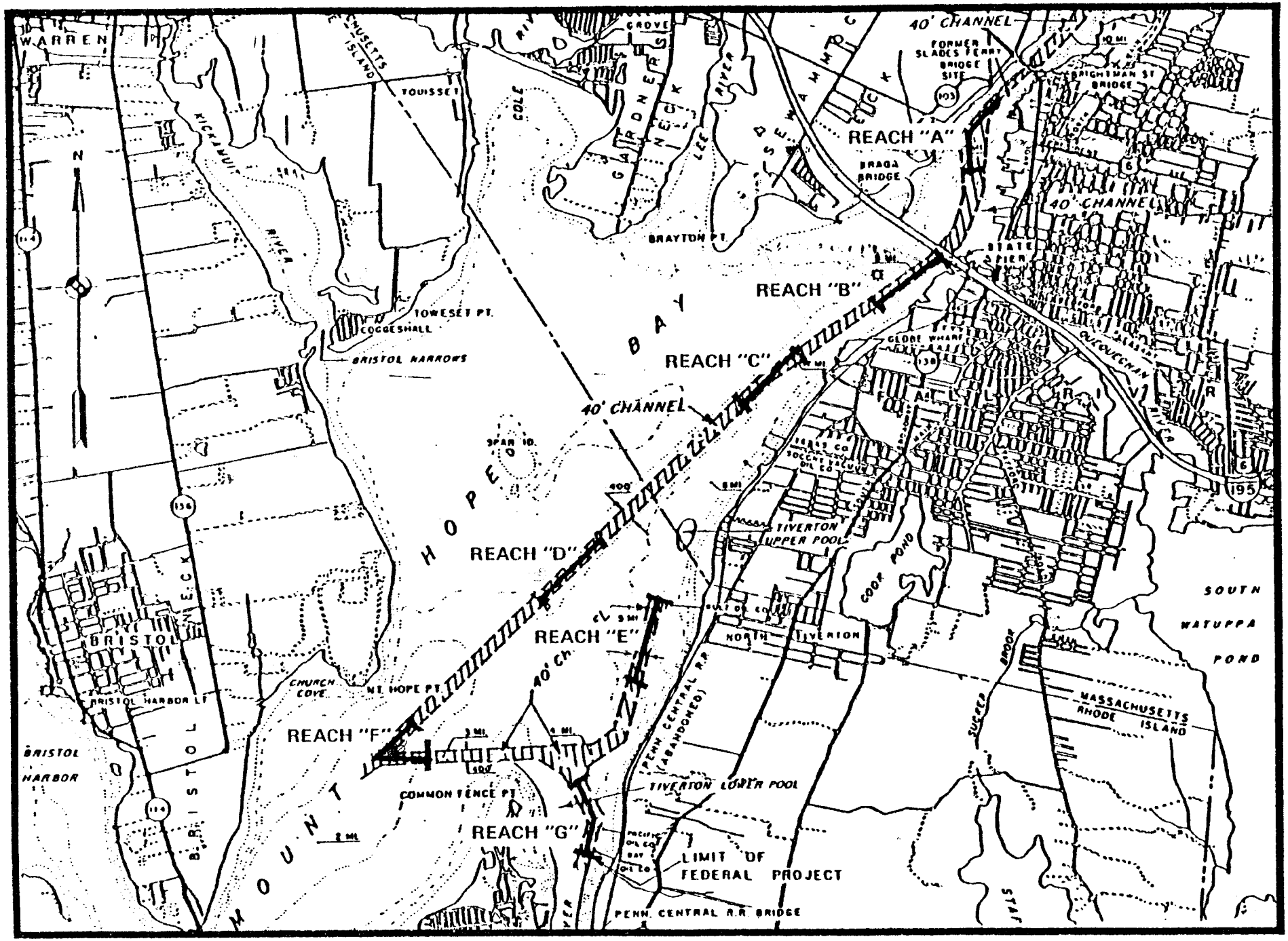

Figure 1.—Locations of proposed dredging sites. Seven reaches of the Taunton River and Mount Hope Bay (Reaches A–G) are candidates for dredging. Samples of sediment were systematically collected with a core sampler from five sites in each reach except Reach B, in which four sites were sampled.

criteria identified in §227.6 (Constituents Prohibited as Other than Trace Contaminants) and §227.13 (Dredged Material) of the regulations is addressed in this evaluation.

The evaluation consists of four principal sections in addition to the Introduction. The first section, which precedes the Introduction, summarizes the ecological acceptability of the proposed discharge operation. The second section reviews the methods and materials employed in the evaluation. The third section presents important results of the evaluation. The fourth section contains references cited in the evaluation. An additional section included in previous reports to the New England Division (NED) - a section that, in part, addresses significantly elevated levels of contaminants in tested organisms in the context of background environmental levels - is omitted in this report at the request of the NED's project officer.

The evaluation contains two appendices. Appendix A details laboratory procedures employed for preparing dredged material and conducting bioassays. The appendix also serves as a quality-control document. Appendix B contains all raw bioassay-related data. Only data directly relevant to the ecological evaluation of the proposed discharge operation are presented in the main body of the evaluation.

2. METHODS AND MATERIALS[a]

Dredged material proposed for oceanic discharge was collected from seven reaches in the study area (Figure 1) during March 7-8, 1981. Material was collected by Briggs Engineering Company with a Benthos core sampler operated from the vessel Min-Flicka.

In each reach of the study area, five systematically selected sites (four sites in Reach B) were sampled to a depth of approximately 0.5 to 2.0 m. LORAN-C coordinates and recorded water depths for these sites are presented in Table 1. Sediment cores obtained from the sites were labelled, sealed, and stored in ice on the vessel until March 9. The cores were then transported to ERCO's Aquatic Toxicology Laboratory in Cambridge, Massachusetts. At the laboratory, all cores from each reach were composited, mixed, and stored in plastic bags at 2-4°C. Cores were placed in cold storage at about 1630 on March 9, 1981.

Dredged material was prepared for biological testing according to procedures described in Appendix B of the manual entitled Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters (U.S. EPA and U.S. Army COE, 1977). Artificial seawater (30 ppt salinity) was employed to formulate liquid and suspended particulate phases of dredged material. During preparation of the liquid and suspended particulate phases, dredged material and artificial seawater were mixed by mechanical methods (as opposed to mixing by compressed air) since anoxic conditions did not occur in the sediment-seawater mixtures. In preparation of

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[a]Laboratory procedures used to prepare dredged material and conduct bioassays are described in detail in Appendix A of this evaluation.

Table 1.—LORAN-C coordinates and recorded water depths for sampling sites

Reach of Study Area	Sampling Site	LORAN-C Coordinates	Recorded Water Depth (m)
A	1	14265.4, 44073.9	7.3
	2	14269.0, 44073.2	7.3
	3	14268.6, 44073.2	7.3
	4[b]	14269.1, 44072.7	7.3
	5[b]	14270.3, 44070.9	9.1
B	1[a]	- -	-
	2[b]	14273.2, 44069.2	11.0
	3[b]	14273.3, 44069.1	11.0
	4	14276.2, 44068.8	11.0
	5	14276.1, 44068.1	11.0
C	1[b]	14281.8, 44068.0	11.0
	2	14282.8, 44067.9	11.0
	3	14283.7, 44067.6	5.5
	4	14284.6, 44066.4	11.0
	5	14286.2, 44066.1	11.0
D	1	14293.4, 44063.4	7.3
	2	14294.1, 44067.2	5.5
	3	14295.1, 44063.0	11.0
	4	14296.5, 44062.8	11.0
	5	14298.5, 44062.2	9.1
E	1	14292.1, 44061.1	9.1
	2	14294.3, 44060.0	9.1
	3	14294.8, 44059.6	9.1
	4[b]	14295.2, 44058.6	7.3-11.0
	5	14296.4, 44058.1	11.0
F	1	14306.9, 44058.9	11.0
	2	14307.9, 44058.4	11.0
	3	14309.8, 44058.2	14.6
	4	14309.6, 44057.0	7.3
	5	14307.4, 44057.5	11.0
G	1	14301.2, 44054.6	11.0
	2	14301.8, 44054.2	11.0
	3	14302.2, 44053.3	11.0
	4	14303.3, 44052.6	10.1
	5[b]	14303.1, 44051.8	11.0

[a]Core samples could not be obtained from this site because of the presence of an impenetrable bottom.

[b]Two sediment cores were collected at these sites. LORAN-C coordinates identify the location at which the first core was obtained.

the liquid phase, centrifugation was not required to reduce concentrations of suspended solids prior to filtration.

Bioassays with dredged material were, with one exception, conducted according to guidelines presented in Appendices D and F of the EPA and COE manual for dredged material (U.S. EPA and U.S. Army COE, 1977). The one exception is that 19-liter aquaria, rather than 38-liter aquaria, were used to conduct liquid and suspended particulate phase bioassays with fish. The use of the smaller aquaria is sanctioned by the EPA in its contemporary procedures for performing bioassays for the Ocean Dumping Permit Program (U.S. EPA, 1978).

Species employed in the liquid and suspended particulate phase bioassays were the copepod (Acartia tonsa), mysid shrimp (Neomysis americana), and Atlantic silverside (Menidia menidia). Copepods were purchased from a commercial supplier in Middletown, Delaware. Mysid shrimp and Atlantic silversides were acquired from a supplier in Salem, Massachusetts. All organisms were acclimated in artificial seawater for at least 3 days prior to use in bioassays. Bioassays were conducted at 20±1°C, the recommended summer testing temperature for the New England region (U.S. EPA and U.S. Army COE, 1977). Artificial seawater was used to dilute liquid and suspended particulate phases to appropriate test concentrations and as a control (culture water control).

Species tested in the solid phase bioassays were the grass shrimp (Palaemonetes pugio), hard clam (Mercenaria mercenaria), and sandworm (Nereis virens). Grass shrimp, hard clams, and sandworms were obtained from commercial suppliers in, respectively, Middletown, Delaware; Long Island, New York; and Boston, Massachusetts. Animals were acclimated in artificial seawater for at least 3 days prior to initiation

of testing. All species were tested in the same aquaria. Testing temperature was again 20±1°C. Water exchange (artificial seawater) was by the replacement, as compared to the flow-through, method. Control (culture) sediment employed in the tests was collected on March 10, 1981, from the subtidal zone off Manchester, Massachusetts. The sediment, which was collected by R. Boeri, ERCO, consisted primarily of sand. Reference (disposal-site) sediment used in the tests was collected during the morning of March 9, 1981, from a single sampling station located approximately 1.25 km southeast of the "DG-A" buoy near the disposal site (LORAN-C coordinates = 14392.1 and 43943.3). The sediment was collected with a Teflon-coated Ponar grab operated from the vessel Min-Flicka by Briggs Engineering Company. R. Boeri of ERCO observed the collection. Depth of water at the sampling station was about 35 m. The sediment was put in plastic bags and placed in cold storage (2-4°C) at ERCO's Aquatic Toxicology Laboratory at approximately 1630 on March 9, 1981.

Mysid shrimp exposed to liquid and suspended particulate phases of dredged material were fed live 48-hr-old Artemia (brine shrimp) nauplii at a rate of approximately 1 ml of culture/1,000-ml culture dish/day. Other organisms were not fed immediately before or during testing.

At the conclusion of the solid-phase bioassays with grass shrimp, hard clams, and sandworms, all surviving organisms from each aquarium (replicate) were placed in an aquarium containing clean, sediment-free water and allowed to void their digestive systems (sand worms were confined in Nitex containers to prevent predation by grass shrimp). Organisms were maintained in uncontaminated media for a period of 2 days. During this time, fecal material was removed from aquaria. At the end of the 2-day period, all samples of

organisms were split into approximately equal amounts. One of these subsamples was placed in a polyethylene clean bag and frozen for later analyses for metals. The second subsample was put in solvent-rinsed aluminum foil and frozen for analyses for organics. Prior to being chemically analyzed, biological samples were thawed and exoskeletons of grass shrimp and hard clams were removed with acid-rinsed plastic utensils (metal analyses) or solvent-rinsed metal utensils (organic analyses).

Biological samples (tissue samples) were analyzed for two metals - cadmium (Cd) and mercury (Hg) - according to procedures described by Goldberg (1976) and the U.S. EPA (1979). In the analyses for Cd, an aliquot of wet, homogenized tissue (approximately 5 g for hard clams and sandworms and 0.3-0.6 g for grass shrimp) was placed in a 100-ml tall-form Pyrex beaker with 5 ml of concentrated, Instra-analyzed (J.T. Baker Co.) nitric acid and refluxed without boiling until the tissue was completely digested (6-24 hr). Following digestion, the sample was evaporated to dryness. Then, additional nitric acid (1-2 ml) and 30% Ultrex (J.T. Baker Co.) hydrogen peroxide (1-2 ml) were added to the beaker, and the sample was heated until oxidative frothing subsided. At this time, the sample was cooled, diluted to volume with deionized, distilled water, and analyzed by graphite-furnace atomic absorption spectrophotometry (AAS). Procedural blanks and standards were evaluated using the same methods employed for tissue samples. For the analyses for Hg, a separate aliquot of wet, homogenized tissue (about 5 g for hard clams and sandworms and 0.3-0.6 g for grass shrimp) was placed in a 300-ml glass BOD bottle. Approximately 15-20 ml of concentrated, Instra-analyzed sulfuric acid was placed in the bottle and the sample was heated at 55°C in a water bath until the tissue was completely digested (2 hr). After cooling of the sample, 100 ml of deionized, distilled water and 1-2 g of Instra-analyzed potassium permanganate

were added to the bottle. The resulting solution was analyzed by cold-vapor AAS after addition of reducing agents (10% hydroxylamine hydrochloride and 10% stannous sulfate). Procedural blanks and standards were assessed by the same methods used for tissue samples.

In the case of Cd, analyses of three samples of oyster tissue from the National Bureau of Standards (NBS-SRM 1566) averaged 4.0 $\pm$ 0.2 µg/g dry wt., as compared to a certified value of 3.5 $\pm$ 0.4 µg/g. Precision of analytical techniques is indicated by values obtained with subsamples of organisms that were employed in bioassays - 0.052, 0.043, and 0.054 µg/g wet wt. (hard clams); and 0.081, 0.078, and 0.077 µg/g (sandworms). Procedural blanks, employed to determine possible contamination of samples by reagents and sample handling, contained an average equivalent of <0.10 µg/g wet wt. (grass shrimp), <0.04 µg/g (hard clams), and <0.040 µg/g (sandworms). In the case of Hg, analyses of three samples of oyster tissue averaged 0.055 $\pm$ 0.014 µg/g dry wt., as compared to a certified value of 0.057 $\pm$ 0.015 µg/g. Precision of analytical techniques is again evidenced by values associated with subsamples of organisms used in bioassays - 0.016, 0.009, and 0.013 µg/g wet wt. (hard clams); and <0.001, 0.005, and <0.001 µg/g (sandworms). Procedural blanks contained an average equivalent of <0.025 µg/g wet wt. (grass shrimp), <0.001 µg/g (hard clams), and <0.001 µg/g (sandworms).

Tissue samples were analyzed for three types of organics - polychlorinated biphenyls (PCBs), the dichloro-diphenyl-trichloroethane family (DDT, DDE, and DDD), and petroleum hydrocarbons - according to procedures described by the U.S. EPA (1971), Crump-Wiesner et al. (1974), the U.S. Food and Drug Administration (1977), and Warner (1976). Tissue samples (5-20 g wet wt.) were placed in 50-ml centrifuge tubes, to

which were added 10-ml aliquots of 10 N potassium hydroxide and high-purity methanol, and 5 µg of an internal standard (androstane). After sealing with nitrogen gas, the tubes were placed in a water bath at 80°C for 4 hr (tubes were shaken every 30 min). This saponification process, described above, digests the tissue, thereby releasing DDTs, PCBs, and petroleum hydrocarbons. Three 20-ml portions of high-purity hexane were used to extract the original compounds of interest from the methanol/potassium hydroxide digestate. The water soluble fraction was then discarded. The three extracts were combined, dried over a small volume (10 g) of sodium sulfate, and concentrated to 1 ml by flash evaporation. The extracts were then fractionated using column chromatography (1 g sodium sulfate, 6.5 g of 7.5% deactivated alumina, and 1 g sodium sulfate) as follows: the 1-ml concentrate was charged to the top of the column and the column was eluted with 25 ml of hexane. The hexane was concentrated to 2 ml by flash evaporation, and further concentrated to 0.5 ml under a stream of purified nitrogen. The hexane fraction (f_1) was analyzed for PCBs and the DDT family by packed-column gas chromatography and electron-capture detection, employing a Hewlett-Packard Model 5840A instrument equipped with a Ni^{66} detector. The column, a 6-ft x 2-mm I.D. glass instrument packed with 5% SP2401 or 1.95% SP2401 and 1.5% SP2250, was held isothermally at 188°C. The peaks in the f_1 fraction were identified and quantified by comparing retention times and peak areas to those of standards. An aliquot of the fraction was analyzed for petroleum hydrocarbons by glass capillary gas chromatography and flame ionization detection, employing a Hewlett-Packard Model 5840A instrument. The column, a 0.25-mm I.D. x 30-m SE30 glass capillary fused silica column (J&W Scientific), was temperature-programmed from 60°C to 275°C at 10°/min. The areas of the resolved and unresolved components were measured by electronic integration and planimetry, respectively, and

compared to the areas of an internal standard (androstane) to determine the concentration of petroleum hydrocarbons.

In the analyses for PCBs, procedural blanks contained less than the detection limit (0.01 µg/g wet wt.) for all species. Precision of analytical techniques is indicated by values obtained with subsamples of organisms that were not employed in bioassays - 0.01, 0.01, and <0.01 µg/g wet wt. (hard clams); and 0.01, 0.03, and 0.03 µg/g (sandworms). In the analyses for the DDT group, procedural blanks, as well as all samples, contained less than detectable levels of the chemicals (0.01 µg/g wet wt.). In the case of petroleum hydrocarbons, procedural blanks contained an average of 1.3 µg/g wet wt. (grass shrimp), 0.1 µg/g (hard clams), and 0.2 µg/g (sandworms). Precision of analytical techniques is again indicated by values obtained with subsamples of organisms not employed in bioassays - 13.7, 10.2, and 10.4 µg/g wet wt. (hard clams); and 12.9, 15.5, and 16.5 µg/g (sandworms).

Results of the bioassay and bioaccumulation studies were interpreted by statistical techniques recommended by the U.S. EPA and U.S. Army COE (1977). When warranted, selected data from each data set generated in the studies were evaluated by Cochran's test to determine if variances of the data were homogeneous (environmentally benign data were not statistically analyzed). If variances of selected data were homogeneous, a parametric one-way analysis of variance (ANOVA) and, if necessary, Student-Newman-Keuls' test was used to determine if significant differences exist between control or reference organisms and organisms exposed to dredged material. If variances were not homogeneous as judged by Cochran's test, the data were transformed (natural logarithm of X + 1), and the transformed data were evaluated

for homogeneity of variances by Cochran's technique. Transformed data exhibiting homogeneous variances were analyzed for significant differences by a parametric one-way ANOVA and, if appropriate, Student-Newman-Keuls' test. When transformed data were characterized by heteroscedasticity, a nonparametric one-way ANOVA (Kruskal and Wallis' test; Sokal and Rohlf, 1969) and, if necessary, Wilcoxon-Mann-Whitney's STP test (Sokal and Rohlf, 1969) was employed to interpret original data. In all statistical tests, the symbols "*(*)" and "ns" are used to denote significant and nonsignificant differences, respectively. Median lethal concentrations (LC50s) were calculated by the moving-average method (Stephan, 1978).

The environmental concentration of the liquid phase of dredged material after the 4-hr period of initial mixing was calculated by the release-zone model (U.S. EPA and U.S. Army COE, 1977; Appendix H). Volume of the initial mixing zone (V_m) was determined by the equation for instantaneous discharge of dredged material or for discharge from a stationary vessel:

$$V_{m_{(m^3)}} = \pi(100)^2 d + 200wd + (200 + w)\ell d, \qquad \text{(Equation 1)}$$

with d (depth of mixing zone), w (width of disposal vessel), and ℓ (length of disposal vessel) assumed to be 20, 18, and 60 m, respectively. Thus, V_m = 961,920 m^3. Volume of the discharged liquid phase (V_w) was derived by the equation:

$$V_{w_{(m^3)}} = \frac{P_b - P_d}{P_w - P_d} (V_T), \qquad \text{(Equation 2)}$$

with P_b (bulk density), P_d (particle density), P_w (liquid phase density), and V_T (volume of disposal vessel) assumed to be 1.5, 2.6, 1.0, and 3,058 m^3, respectively. Therefore, V_w = 2,102 m^3. Environmental concentration of the liquid phase after initial mixing (C_w) was calculated by the equation:

$$C_{w(\%)} = \frac{V_w}{V_m} (100) = \frac{2{,}102\ m^3}{961{,}920\ m^3} (100) = 0.22\%. \quad \text{(Equation 3)}$$

3. RESULTS

The samples of dredged material employed in the evaluation consisted primarily of black clayey silt (visual determination). The reference (disposal-site) sediment was similar in texture to the samples of dredged material and contained a number of sandworms.

3.1 Bioassay Studies

Bioassay studies performed during the evaluation consisted of liquid and suspended particulate phase bioassays and solid phase tests.

3.1.1 Liquid and Suspended Particulate Phase Bioassays

Analyses of results of liquid and suspended particulate phase bioassays are presented according to the same format since the analyses are based on identical components (U.S. EPA and U.S. Army COE, 1977): (1) selection of an appropriate control for comparison to test results (when disposal-site water as well as culture water is used for control purposes), (2) statistical comparison of survival of organisms exposed for 96 hr to the appropriate control and 100% liquid/suspended particulate phase, (3) calculation or estimation of a "worst-case" exposure-time-dependent LC50 and associated 95% confidence interval for the liquid/suspended particulate phase (if survival in 100% liquid/suspended particulate phase is significantly less than survival in the appropriate control), (4) derivation of an exposure-time-dependent limiting permissible concentration (LPC) for the liquid/suspended particulate phase by multiplying the lower limit of the 95% confidence interval

of the worst-case LC50 for the phase by 1% or a pragmatically determined application factor, and (5) graphical comparison of the LPC for the liquid/suspended particulate phase to the estimated environmental concentration ("dilution curve") of the phase as determined, in all probability, by the release-zone model.

3.1.1.1 Liquid Phase Bioassays

Data produced by liquid phase bioassays with copepods, mysid shrimp, and Atlantic silversides are presented in, respectively, Tables B1, B2, and B3 (Appendix B). Mean survival of organisms exposed for 96 hr to 100% phase was 20.0-90.0% (copepods), 93.3-100.0% (mysid shrimp), and 83.3-100.0% (Atlantic silversides).

Analyses of survival data for copepods, mysid shrimp, and Atlantic silversides exposed for 96 hr to culture water control and 100% liquid phase of dredged material are presented in Tables 2-4, respectively. In the case of all species, mean survival in the control test was greater than 90%, thus permitting further analyses of data.

Survival data for copepods (Table 2), mysid shrimp (Table 3), and Atlantic silversides (Table 4) exhibited homogeneous variances, as judged by Cochran's test. Therefore, parametric ANOVAs were employed to determine if critical subsets of the three data sets are characterized by significant differences (the "t" test described in §25, Appendix D of the EPA and COE manual for dredged material [U.S. EPA and U.S. Army COE, 1977] is not appropriate for use with more than one sample of dredged material and a control).

Table 2. Analysis of survival data for copepods, Acartia tonsa, exposed for 96 hr to culture water control and 100% liquid phase of dredged material

Step 1. Survival Data (From Table B1)

Replicate (r)	Treatment (t):	Number of Survivors							
		Culture Water Control	Dredged Material						
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		10	0	6	6	8	9	8	5
2		9	4	9	9	8	9	9	7
3		9	2	6	6	9	8	10	7
	Mean ($\bar{x}$):	9.33	2.00	7.00	7.00	8.33	8.67	9.00	6.33
		(93.3%)	(20.0%)	(70.0%)	(70.0%)	(83.3%)	(86.7%)	(90.0%)	(63.3%)

Step 2. Cochran's Test for Homogeneity of Variances of Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.33	0.33
Dredged Material - Reach A	2.00	4.00
Dredged Material - Reach B	7.00	3.00
Dredged Material - Reach C	7.00	3.00
Dredged Material - Reach D	8.33	0.33
Dredged Material - Reach E	8.67	0.33
Dredged Material - Reach F	9.00	1.00
Dredged Material - Reach G	6.33	1.33

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{4.00}{13.32} = 0.30 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.52$ for $\alpha = 0.05$, $k = 8$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Survival Data

Source of Variation	df	Sum of Squares	Mean Square	F(cal.)	
Treatment (Culture Water Control; Dredged Material - Reaches A through G)	t-1=7	117.30	16.76	9.98 **	as compared to $F_{(tab.)} = 4.03$ for $\alpha = 0.01$, numerator df = 7, and denominator df = 16
Error	t(r-1)=16	26.67	1.67		
Total	tr-1=23	143.97			

Table 3. Analysis of survival data for mysid shrimp, Neomysis americana, exposed for 96 hr to culture water control and 100% liquid phase of dredged material

Step 1. Survival Data (From Table B2)

Replicate (r)	Treatment (t):	Number of Survivors							
		Culture Water Control	Dredged Material						
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		9	9	10	10	9	9	10	9
2		10	10	10	10	10	10	10	10
3		10	10	9	10	9	10	10	10
	Mean ($\bar{x}$):	9.67	9.67	9.67	10.00	9.33	9.67	10.00	9.67
		(96.7%)	(96.7%)	(96.7%)	(100.0%)	(93.3%)	(96.7%)	(100.0%)	(96.7%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.67	0.33
Dredged Material - Reach D	9.33	0.33

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.33}{0.66} = 0.50 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.98$ for $\alpha = 0.05$, $k = 2$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data

Source of Variation	df	Sum of Squares	Mean Square	F(cal.)	
Treatment (Culture Water Control; Dredged Material - Reach D)	t-1=1	0.17	0.17	0.52 ns,	as compared to $F_{(tab.)} = 7.71$ for $\alpha = 0.05$, numerator df = 1, and denominator df = 4
Error	t(r-1)=4	1.33	0.33		
Total	tr-1=5	1.50			

Table 4. Analysis of survival data for Atlantic silversides, Menidia menidia, exposed for 96 hr to culture water control and 100% liquid phase of dredged material

Step 1. Survival Data (From Table B3)

Replicate (r)	Treatment (t):	Number of Survivors							
		Culture Water Control	Dredged Material						
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		9	10	10	10	10	9	10	10
2		10	10	8	10	10	6	10	10
3		10	10	10	10	9	10	9	10
	Mean ($\bar{x}$):	9.67	10.00	9.33	10.00	9.67	8.33	9.67	10.00
		(96.7%)	(100.0%)	(93.3%)	(100.0%)	(96.7%)	(83.3%)	(96.7%)	(100.0%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.67	0.33
Dredged Material - Reach B	9.33	1.33
Dredged Material - Reach E	8.33	4.33

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{4.33}{5.99} = 0.72 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.87$ for $\alpha = 0.05$, $k = 3$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Culture Water Control; Dredged Material - Reaches B and E)	t-1=2	2.89	1.44	0.72 ns,	as compared to $F_{(tab.)} = 5.14$ for $\alpha = 0.05$, numerator df = 2, and denominator df = 6
Error	t(r-1)=6	12.00	2.00		
Total	tr-1=8	14.89			

Results of the ANOVAs for mysid shrimp (Table 3) and Atlantic silversides (Table 4) indicate no statistically significant differences ($\alpha = 0.05$) in survival of organisms exposed to 100% liquid phase of dredged material and survival of control animals.[a] Only in the case of copepods (Table 2) does a significant difference exist. However, the exposure-time-dependent LPC, which is based on the lowest survival data for copepods (organisms tested with dredged material from Reach A of the sampling area) is greater than the environmental concentration of the phase at the end of initial mixing (Figure 2). In addition, the lines representing the LPC and environmental concentration of the phase show no indication of converging as a function of time. Consequently, it is concluded that, with regard to its toxicological effects, the liquid phase of the dredged material is environmentally acceptable for discharge to the ocean (U.S. EPA and U.S Army COE, 1977).

3.1.1.2 Suspended Particulate Phase Bioassays

Data generated by suspended particulate phase bioassays with copepods, mysid shrimp, and Atlantic silversides are presented in, respectively, Tables B4, B5, and B6 (Appendix B). Mean survival of organisms exposed for 96 hr to 100% phase was 83.3-100.0% (copepods), 93.3-100.0% (mysid shrimp), and 90.0-100.0% (Atlantic silversides).

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[a]Paragraph 28, page D13, Appendix D of the EPA and COE manual for dredged material (U.S. EPA and U.S. Army COE, 1977) specifies that "when no differences are detected between control and test survival after 96 hr, the analysis may be considered complete at this point with no indication of potential impact of the liquid (or suspended particulate) phase if the proposed disposal operation occurs." Thus, further analyses relating to LC50's and associated confidence intervals, LPC's, and environmental concentrations of the phase are not warranted.

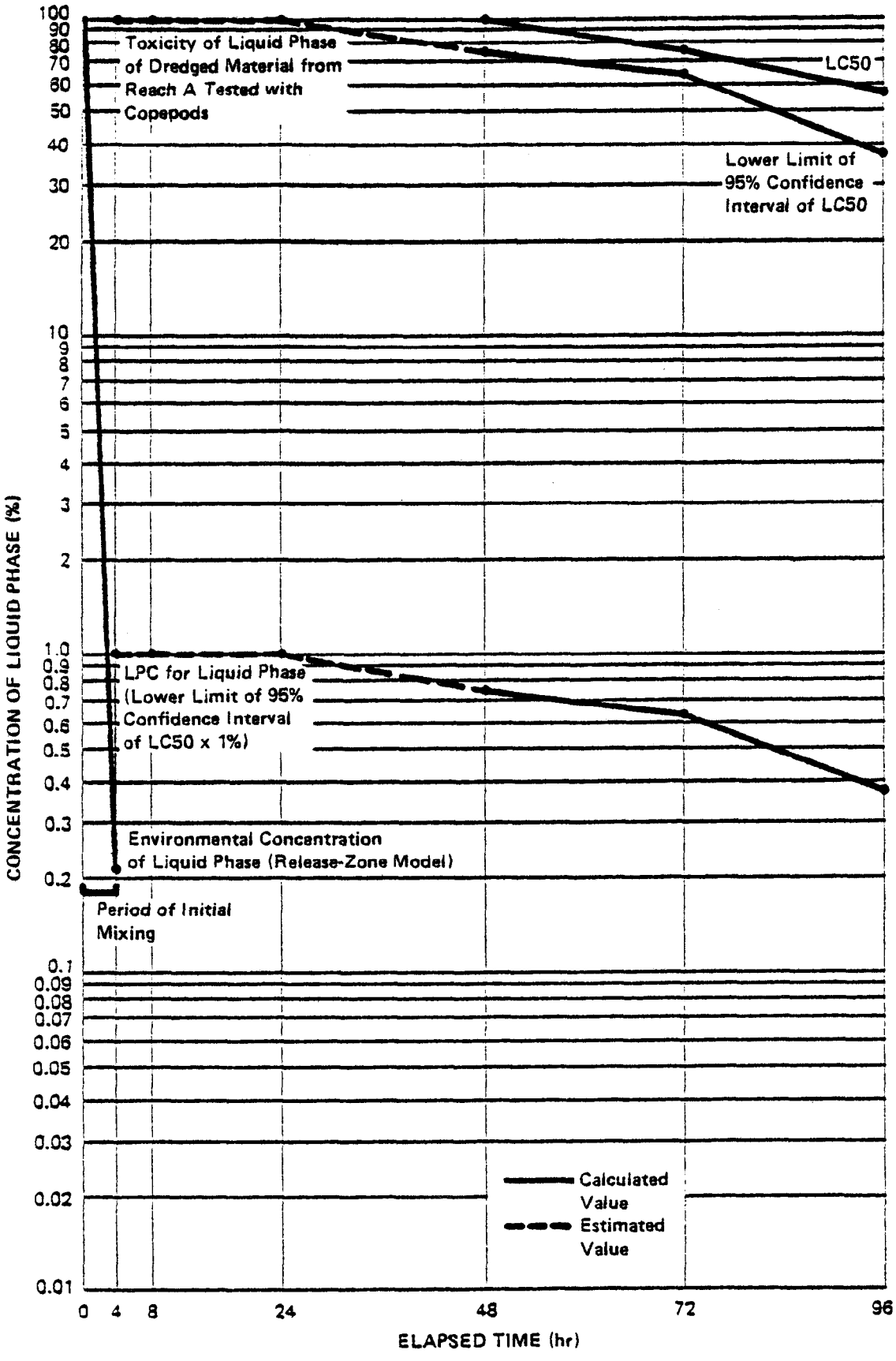

Figure 2.—Comparison of exposure-time-dependent limiting permissible concentration (LPC) for liquid phase of dredged material and environmental concentration of liquid phase after initial mixing. The LPC is based on the bioassay conducted with the liquid phase of dredged material from Reach A of the sampling area and copepods, *Acartia tonsa*. The exposure-time-dependent median lethal concentration (LC50) was calculated by the moving-average method to be: 48 hr—100% phase (95% confidence interval=77—>100%); 72 hr—75% phase (61—95%); and 96 hr—58% phase (38—100%).

Analyses of survival data for copepods, mysid shrimp, and Atlantic silversides exposed for 96 hr to culture water control and 100% suspended particulate phase of dredged material are presented in Tables 5-7, respectively. Mean survival of all species exposed to the culture water control was greater than 90%, thereby allowing further analyses of data.

Survival data for all species indicate no statistically significant differences ($\alpha = 0.05$) in survival of organisms exposed to culture water control and 100% suspended particulate phase of dredged material (Tables 5, 6, and 7). Therefore, it is concluded that, in terms of its toxicological effects, the suspended particulate phase of the dredged material is ecologically acceptable for oceanic discharge.

3.1.2 Solid Phase Bioassays

Results of solid phase bioassays, unlike results of liquid and suspended particulate phase tests, are analyzed almost exlusively according to statistical techniques. The concepts of LC50s and related confidence intervals, LPCs, and models of environmental fate of discharged material are not applicable.

Data produced by solid phase bioassays with grass shrimp, hard clams, and sandworms are presented in Table B7 (Appendix B). Mean survival of organisms exposed for 10 days to dredged material was 98.0-100.0% (grass shrimp), 96.0-100.0% (hard clams), and 75.0-90.0% (sandworms).

Analysis of total (combined) survival data for the three species exposed for 10 days to control (culture) sediment, reference (disposal-site) sediment, and the solid phase of the dredged material is presented in Table 8. Mean survival of

Table 5. Analysis of survival data for copepods, Acartia tonsa, exposed for 96 hr to culture water control and 100% suspended particulate phase of dredged material

Step 1. Survival Data (From Table B4)

Replicate (r)	Treatment (t):	Number of Survivors						
		Culture Water Control	Dredged Material					
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		10	6	10	9	10	10	8	8
2		9	9	9	10	8	10	10	9
3		9	10	10	6	9	10	9	8
	Mean ($\bar{x}$):	9.33	8.33	9.67	8.33	9.00	10.00	9.00	8.33
		(93.3%)	(83.3%)	(96.7%)	(83.3%)	(90.0%)	(100.0%)	(90.0%)	(83.3%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.33	0.33
Dredged Material - Reach A	8.33	4.33
Dredged Material - Reach C	8.33	4.33
Dredged Material - Reach D	9.00	1.00
Dredged Material - Reach F	9.00	1.00
Dredged Material - Reach G	8.33	0.33

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{4.33}{11.32} = 0.38 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.62$ for $\alpha = 0.05$, $k = 6$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Culture Water Control; Dredged Material - Reaches A, C, D, F, and G)	t-1=5	2.94	0.59	0.31 ns,	as compared to $F_{(tab.)} = 3.11$ for $\alpha = 0.05$, numerator df = 5, and denominator df = 12
Error	t(r-1)=12	22.67	1.89		
Total	tr-1=17	25.61			

Table 6. Analysis of survival data for mysid shrimp, Neomysis americana, exposed for 96 hr to culture water control and 100% suspended particulate phase of dredged material

Step 1. Survival Data (From Table B5)

Replicate (r)	Treatment (t):	Number of Survivors						
		Culture Water Control	Dredged Material					
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		9	8	10	10	10	10	10	10
2		10	10	10	10	10	10	10	10
3		10	10	10	10	10	10	10	10
	Mean ($\bar{x}$):	9.67	9.33	10.00	10.00	10.00	10.00	10.00	10.00
		(96.7%)	(93.3%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.67	0.33
Dredged Material - Reach A	9.33	1.33

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{1.33}{1.66} = 0.80 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.98$ for $\alpha = 0.05$, $k = 2$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Culture Water Control; Dredged Material - Reach A)	t-1=1	0.17	0.17	0.20 ns,	as compared to $F_{(tab.)} = 7.71$ for $\alpha = 0.05$, numerator df = 1, and denominator df = 4
Error	t(r-1)=4	3.33	0.83		
Total	tr-1=5	3.50			

Table 7. Analysis of survival data for Atlantic silversides, Menidia menidia, exposed for 96 hr to culture water control and 100% suspended particulate phase of dredged material

Step 1. Survival Data (From Table B6)

Replicate (r)	Treatment (t):	Number of Survivors						
		Culture Water Control	Dredged Material					
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1		9	8	10	10	9	10	9	9
2		10	10	10	9	10	10	10	8
3		10	8	8	10	10	10	9	10
	Mean ($\bar{x}$):	9.67	9.00	9.33	9.67	9.67	10.00	9.33	9.00
		(96.7%)	(90.0%)	(93.3%)	(96.7%)	(96.7%)	(100.0%)	(93.3%)	(90.0%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Culture Water Control	9.67	0.33
Dredged Material - Reach A	9.00	1.00
Dredged Material - Reach B	9.33	1.33
Dredged Material - Reach F	9.33	0.33
Dredged Material - Reach G	9.00	1.00

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{1.33}{3.99} = 0.33 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.68$ for $\alpha = 0.05$, $k = 5$, and $v = 2$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Culture Water Control; Dredged Material - Reaches A, B, F, and G)	t-1=4	0.93	0.23	0.29 ns,	as compared to $F_{(tab.)} = 3.48$ for $\alpha = 0.05$, numerator df = 4, and denominator df = 10
Error	t(r-1)=10	8.00	0.80		
Total	tr-1=14	8.93			

Table 8. Analysis of total (combined) survival data for grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) exposed for 10 days to control (culture) sediment, reference (disposal-site) sediment, and solid phase of dredged material

Step 1. Survival Data (From Table B7)

Treatment (t): / Replicate (r)	Number of Survivors								
	Control (Culture) Sediment	Reference (Disposal-Site) Sediment	Dredged Material						
			Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	59	57	54	55	57	58	57	57	54
2	57	58	60	57	56	58	53	56	58
3	60	57	55	58	60	57	58	58	56
4	59	58	45	56	59	57	55	59	55
5	60	52	59	52	56	52	60	57	58
Mean ($\bar{x}$):	59.00	56.40	54.60	55.60	57.60	56.40	56.60	57.40	56.20
	(98.3%)	(94.0%)	(91.0%)	(92.7%)	(96.0%)	(94.0%)	(94.3%)	(95.7%)	(93.7%)

Step 2. Cochran's Test for Homogeneity of Variances of Selected Survival Data

Treatment (t)	Number of Survivors	
	Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	56.40	6.30
Dredged Material - Reach A	54.60	35.30
Dredged Material - Reach B	55.60	5.30
Dredged Material - Reach G	56.20	3.20

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{35.30}{50.10} = 0.70\ *,$$

as compared to: $C_{(tab.)} = 0.63$ for $\alpha = 0.05$, $k = 4$, and $v = 4$

Step 3. Nonparametric One-Way Analysis of Variance (ANOVA) of Selected Survival Data (Kruskal and Wallis' Test)

$$H = \left[\frac{12}{tr(tr+1)}\right]\left[\sum_t \frac{R_t^2}{r}\right] - 3(tr+1)$$

$$H = \left[0.029\right]\left[\frac{58.5^2 + 51.5^2 + 47.0^2 + 53.0^2}{5}\right] - 63 = 3.4\ ns,$$

as compared to: $\chi^2 = 7.8$ for $\alpha = 0.05$ and 3 df

control organisms was greater than 90%, thus allowing evaluation of data from tests with reference sediment and dredged material. Survival of organisms exposed to the solid phase of dredged material was not significantly lower than survival of reference organisms. Thus, it is concluded that, with regard to its toxicological effects, the solid phase of the dredged material is ecologically acceptable for discharge to the disposal site near Brenton Reef.[a]

3.2 Bioaccumulation Studies

Concentrations of the DDT family in tissues of all grass shrimp, hard clams, and sandworms that survived 10-day exposure to the solid phase of dredged material and reference (disposal-site) sediment were less than the detection limit of 0.01 µg/g wet wt. Mean levels of Cd (Table 9), Hg (Table 10), and PCBs (Table 11) in all tested organisms were not significantly elevated ($\alpha = 0.05$) above reference levels.[b] However, there was a statistically important ($\alpha = 0.05$) uptake of petroleum hydrocarbons in hard clams exposed to dredged material from Reach C of the study area (Table 12). Although

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[a]Paragraph 37, page F17, Appendix F of the EPA and COE manual for dredged material (U.S. EPA and U.S. Army COE, 1977) states that a solid phase has "real potential for causing environmentally unacceptable impacts on benthic organisms [only if] difference in mean survival between animals in the control and test sediments is statistically significant and [emphasis added] greater than 10 percent."

[b]Paragraph 25, page G11, Appendix G of the EPA and COE manual for dredged material (U.S. EPA and U.S. Army COE, 1977) states that there is "no indication of potential bioaccumulation from [the solid phase of] the dredged material [if there are] no statistical differences between tissue concentration in the reference substrate controls and the dredged material."

Table 9. Analyses of cadmium (Cd) in tissues of grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) that survived 10-day exposure to reference (disposal-site) sediment and solid phase of dredged material

Organism: Grass Shrimp — Analysis

Step 1. Concentration of Metal in Tissue

Treatment (t):	Reference (Disposal-Site)	Concentration (µg/g wet wt.)						
		Dredged Material						
Replicate (r)	Sediment	Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	<0.10	0.065	<0.077	<0.085	<0.080	<0.14	<0.078	<0.094
2	0.10	<0.074	<0.081	0.12	<0.080	<0.12	<0.095	<0.12
3	<0.079	<0.079	<0.14	<0.10	<0.093	<0.11	<0.11	<0.14
4	<0.084	<0.068	<0.10	<0.13	<0.16	<0.078	<0.084	<0.10
5	<0.11	<0.065	<0.096	<0.092	<0.11	<0.13	<0.089	0.092
Mean ($\bar{x}$):	0.095	0.070	0.099	0.105	0.105	0.116	0.091	0.109

Step 2. Cochran's Test for Homogeneity of Variances of Selected Metal Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.095	0.0002
Dredged Material - Reach B	0.099	0.0006
Dredged Material - Reach C	0.105	0.0004
Dredged Material - Reach D	0.105	0.0011
Dredged Material - Reach E	0.116	0.0006
Dredged Material - Reach G	0.109	0.0004

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.0011}{0.0033} = 0.33 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.48$ for $\alpha = 0.05$, $k = 6$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Metal Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches B, C, D, E, and G)	t-1=5	0.00138	0.00028	0.52 ns,	as compared to $F_{(tab.)} = 2.62$ for $\alpha = 0.05$, numerator df = 5, and denominator df = 24
Error	t(r-1)=24	0.01298	0.00054		
Total	tr-1=29	0.01436			

Boy is that consistent! Almost, maybe too consistent.

Table 9. Continued

Organism	Analysis

Hard Clams

Step 1. Concentration of Metal in Tissue

Treatment (t): / Replicate (r)	Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material						
		Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	0.16	0.14	0.14	0.18	0.17	0.16	0.16	0.13
2	0.15	0.15	0.20	0.15	0.16	0.16	0.16	0.16
3	0.16	0.15	0.15	0.15	0.17	0.17	0.19	0.13
4	0.18	0.15	0.15	0.19	0.21	0.14	0.18	0.21
5	0.19	0.14	0.18	0.18	0.18	0.22	0.17	0.21
Mean ($\bar{x}$):	0.17	0.15	0.16	0.17	0.18	0.17	0.17	0.17

Step 2. Cochran's Test for Homogeneity of Variances of Selected Metal Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.17	0.00027
Dredged Material - Reach D	0.18	0.00037

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.00037}{0.00064} = 0.58 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.91$ for $\alpha = 0.05$, $k = 2$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Metal Data

Source of Variation	df	Sum of Squares	Mean Square	F(cal.)	
Treatment (Reference Sediment; Dredged Material - Reach D)	t-1=1	0.00025	0.00025	0.78 ns,	as compared to $F_{(tab.)} = 5.32$ for $\alpha = 0.05$, numerator df = 1, and denominator df = 8
Error	t(r-1)=8	0.00256	0.00032		
Total	tr-1=9	0.00281			

Table 9. Continued

Organism	Analysis

Sandworms

Step 1. Concentration of Metal in Tissue

Replicate (r)	Treatment (t): Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material: Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	0.091	0.085	0.075	0.090	0.096	0.11	0.099	0.093
2	0.10	0.080	0.061	0.085	0.093	0.17	0.086	0.090
3	0.086	0.088	0.072	0.079	0.10	0.089	0.099	0.090
4	0.091	0.093	0.083	0.081	0.11	0.084	0.089	0.11
5	0.10	0.074	0.093	0.088	0.085	0.079	0.089	0.088
Mean ($\bar{x}$):	0.094	0.084	0.077	0.085	0.097	0.106	0.092	0.094

Step 2. Cochran's Test for Homogeneity of Variances of Selected Metal Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.094	0.00004
Dredged Material - Reach D	0.097	0.00008
Dredged Material - Reach E	0.106	0.00140

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.00140}{0.00152} = 0.92\ *,$$

as compared to: $C_{(tab.)} = 0.75$ for $\alpha = 0.05$, $k = 3$, and $v = 4$

Step 3. Nonparametric One-Way Analysis of Variance (ANOVA) of Selected Metal Data (Kruskal and Wallis' Test)

$$H = \left[\frac{12}{tr(tr+1)}\right]\left[\sum_t \frac{R_t^2}{r}\right] - 3(tr+1)$$

$$H = \left[0.050\right]\left[\frac{39^2 + 44.5^2 + 36.5^2 + 36.5^2}{5}\right] - 48 = 0.3 \text{ ns},$$

as compared to: $\chi^2 = 6.0$ for $\alpha = 0.05$ and 2 df

Table 10. Analyses of mercury (Hg) in tissues of grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) that survived 10-day exposure to reference (disposal-site) sediment and solid phase of dredged material

Organism	Analysis							
Grass Shrimp	Step 1. Concentration of Metal in Tissue							
	Treatment (t):	Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.)						
			Dredged Material						
	Replicate (r)		Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
	1	0.084	0.041	0.051	0.053	0.010	0.042	0.087	0.089
	2	0.089	0.047	0.058	0.051	0.078	0.071	0.075	0.13
	3	0.073	0.035	0.049	0.051	0.059	0.086	0.061	0.049
	4	0.10	0.070	0.084	0.038	0.052	0.077	0.088	0.074
	5	0.058	0.080	0.076	0.010	0.064	0.054	0.096	0.057
	Mean ($\bar{x}$):	0.081	0.055	0.064	0.059	0.071	0.066	0.081	0.080
	- - - - - - Further Analysis Not Warranted - - - - -								
	$\bar{x}$ for dredged material less than or equal to $\bar{x}$ for reference sediment								

Table 10. Continued

Organism	Analysis

Hard Clams

Hg

Step 1. Concentration of Metal in Tissue

Treatment (t): Replicate (r)	Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material						
		Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	0.019	0.018	0.016	0.015	0.015	0.017	0.015	0.017
2	0.018	0.019	0.018	0.016	0.015	0.015	0.015	0.018
3	0.017	0.016	0.014	0.016	0.013	0.017	0.018	0.016
4	0.021	0.019	0.016	0.030	0.016	0.017	0.018	0.030
5	0.022	0.016	0.027	0.030	0.019	0.026	0.019	0.022
Mean ($\bar{x}$):	0.019	0.018	0.018	0.021	0.016	0.018	0.017	0.021

Step 2. Cochran's Test for Homogeneity of Variances of Selected Metal Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.019	0.000004
Dredged Material - Reach C	0.021	0.000062
Dredged Material - Reach G	0.021	0.000033

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.000062}{0.000099} = 0.63 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.75$ for $\alpha = 0.05$, $k = 3$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Metal Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches C and G)	t-1=2	0.000010	0.000005	0.15 ns,	as compared to $F_{(tab.)} = 3.89$ for $\alpha = 0.05$, numerator df = 2, and denominator df = 12
Error	t(r-1)=12	0.000396	0.000033		
Total	tr-1=14	0.000406			

Table 10. Continued

Organism	Analysis

Sandworms

Step 1. Concentration of Metal in Tissue

Replicate (r)	Treatment (t): Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2	<0.001	<0.001	<0.001	0.001	<0.001	0.002	<0.001	0.009
3	<0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	<0.001
4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
5	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.004	0.004
Mean ($\bar{x}$):	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003

Step 2. Cochran's Test for Homogeneity of Variances of Selected Metal Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.001	0
Dredged Material - Reach E	0.002	0.0000007
Dredged Material - Reach F	0.002	0.0000017
Dredged Material - Reach G	0.003	0.0000122

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.0000122}{0.0000146} = 0.92\ *,$$

as compared to: $C_{(tab.)} = 0.63$ for $\alpha = 0.05$, $k = 4$, and $v = 4$

Step 3. Nonparametric One-Way Analysis of Variance (ANOVA) of Selected Metal Data (Kruskal and Wallis' Test)

$$H = \left[\frac{12}{tr(tr+1)}\right]\left[\sum_t \frac{R_t^2}{r}\right] - 3(tr+1)$$

$$H = \left[0.029\right]\left[\frac{35^2 + 61^2 + 54.5^2 + 59.5^2}{5}\right] - 63 = 3.4\ ns,$$

as compared to: $\chi^2 = 7.8$ for $\alpha = 0.05$ and 3 df

Table 11. Analyses of polychlorinated biphenyls (PCBs) in tissues of grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) that survived 10-day exposure to reference (disposal-site) sediment and solid phase of dredged material

Organism	Analysis[a]

Grass Shrimp

Step 1. Concentration of Chemicals in Tissue

Treatment (t): Replicate (r)	Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	-	0.09	-	-	0.04	-	0.03	0.03
2	0.10	-	-	0.01	0.10	0.01	0.02	0.01
3	0.03	0.07	0.02	-	0.10	-	0.03	0.01
4	0.03	0.07	0.02	0.01	-	-	0.01	0.05
5	0.01	0.03	0.01	-	0.03	0.02	-	0.01
Mean ($\bar{x}$):	0.04	0.06	0.02	0.01	0.07	0.02	0.02	0.02

Step 2. Cochran's Test for Homogeneity of Variances of Selected Chemical Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.04	0.00156
Dredged Material - Reach A	0.06	0.00063
Dredged Material - Reach D	0.07	0.00142

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{0.00156}{0.00361} = 0.43 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.80$ for $\alpha = 0.05$, $k = 3$, and $v = 3$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Chemical Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches A and D)	t-1=2	0.00152	0.00076	0.63 ns,	as compared to $F_{(tab.)} = 4.26$ for $\alpha = 0.05$, numerator df = 2, and denominator df = 9
Error	t(r-1)=9	0.01085	0.00121		
Total	tr-1=11	0.01237			

[a]A fire in one of the processing ovens destroyed several samples of tissue, resulting in the loss of some data.

Table 11. Continued

Organism	Analysis[a]

Hard Clams — PCB

Step 1. Concentration of Chemicals in Tissue

Replicate (r)	Treatment (t): Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material: Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.01	0.02
2	0.01	0.01	<0.01	0.02	0.01	0.02	0.01	0.02
3	<0.01	-	0.02	0.01	0.01	0.02	<0.01	0.01
4	0.01	0.01	0.02	0.01	0.01	0.03	<0.01	<0.01
5	0.01	0.01	0.03	0.01	0.03	0.01	0.01	0.01
Mean ($\bar{x}$):	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01

Step 2. Cochran's Test for Homogeneity of Variances of Selected Chemical Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	0.01	0
Dredged Material - Reach B	0.02	0.00007
Dredged Material - Reach E	0.02	0.00007

$$C_{(cal.)} = \frac{s^2_{(max.)}}{\Sigma s^2} = \frac{0.00007}{0.00014} = 0.50 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.75$ for $\alpha = 0.05$, $k = 3$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Chemical Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches B and E)	t-1=2	0.00021	0.00010	2.00 ns,	as compared to $F_{(tab.)} = 3.89$ for $\alpha = 0.05$, numerator df = 2, and denominator df = 12
Error	t(r-1)=12	0.00056	0.00005		
Total	tr-1=14	0.00077			

Table 11. Continued

Organism	Analysis[a]							
Sandworms PCB	Step 1. Concentration of Chemicals in Tissue							
	Concentration (µg/g wet wt.)							
Treatment (t):		Dredged Material						
Replicate (r)	Reference (Disposal-Site) Sediment	Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	0.02	0.04	0.03	0.02	0.05	0.01	0.02	0.01
2	0.03	0.02	0.02	0.03	0.04	0.01	0.03	0.02
3	0.06	0.01	0.01	0.03	0.02	0.02	0.01	0.01
4	-	0.02	0.02	0.02	0.03	0.02	0.01	0.01
5	0.03	0.01	0.02	0.04	0.03	0.01	0.03	0.02
Mean ($\bar{x}$):	0.04	0.02	0.02	0.03	0.03	0.01	0.02	0.01

- - - - - - Further Analysis Not Warranted - - - - -

$\bar{x}$ for dredged material less than $\bar{x}$ for reference sediment

Table 12. Analyses of petroleum hydrocarbons in tissues of grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens) that survived 10-day exposure to reference (disposal-site) sediment and solid phase of dredged material

Organism	Analysis[a]

Grass Shrimp

Step 1. Concentration of Chemicals in Tissue

Treatment (t):	Concentration (µg/g wet wt.)						
		Dredged Material					
Replicate (r)	Reference (Disposal-Site) Sediment	Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	-	10.4	-	-	7.2	-	9.3	13.3
2	22.7	-	-	26.2	15.6	7.7	7.9	20.8
3	5.6	4.4	24.9	9.9	6.9	11.4	18.5	13.5
4	5.2	6.3	4.6	6.3	17.8	22.1	10.8	17.9
5	4.6	8.2	5.9	-	8.8	7.0	5.4	6.6
Mean ($\bar{x}$):	9.5	7.3	11.8	14.1	11.3	12.0	10.4	14.4

Step 2. Cochran's Test for Homogeneity of Variances of Selected Chemical Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	9.5	77.3
Dredged Material - Reach B	11.8	129.1
Dredged Material - Reach C	14.1	112.4
Dredged Material - Reach D	11.3	25.8
Dredged Material - Reach E	12.0	48.6
Dredged Material - Reach F	10.4	24.6
Dredged Material - Reach G	14.4	29.0

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{129.1}{446.8} = 0.29 \text{ ns},$$

as compared to: $C_{(tab.)} = 0.48$ for $\alpha = 0.05$, $k = 7$, and $v = 3$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Chemical Data

Source of Variation	df	Sum of Squares	Mean Square	F(cal.)	
Treatment (Reference Sediment; Dredged Material - Reaches B through G)	t-1=6	82.98	13.83	0.26 ns,	as compared to $F_{(tab.)} = 2.55$ for $\alpha = 0.05$, numerator df = 6, and denominator df = 22
Error	t(r-1)=22	1,178.39	53.56		
Total	tr-1=28	1,261.37			

[a]A fire in one of the processing ovens destroyed several samples of tissue, resulting in the loss of some data.

Table 12. Continued

Organism	Analysis[a]

Hard Clams P. M.

Step 1. Concentration of Chemicals in Tissue

Replicate (r)	Treatment (t): Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	8.6	7.1	13.0	12.9	7.9	8.9	13.6	10.9
2	4.8	6.7	6.3	17.3	7.6	11.1	13.2	9.6
3	9.1	7.6	16.1	7.3	5.4	12.7	15.3	8.8
4	7.7	-	11.0	26.5	6.8	4.6	3.7	10.1
5	~~11.7~~ 41.5	5.8	~~15.7~~ 62.1	~~21.5~~ 95.5	13.8	~~6.4~~ 43.7	~~6.8~~ 52.6	~~11.4~~ 53.8
Mean ($\bar{x}$):	8.4	6.8	12.4	17.1	8.3	8.7	10.5	10.2

Step 2. Cochran's Test for Homogeneity of Variances of Selected Chemical Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	8.4	6.2
Dredged Material - Reach B	12.4	16.0
Dredged Material - Reach C	17.1	55.4
Dredged Material - Reach E	8.7	11.0
Dredged Material - Reach F	10.5	25.0
Dredged Material - Reach G	10.2	1.1

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{55.4}{114.7} = 0.48 \text{ ns,}$$

as compared to: $C_{(tab.)} = 0.48$ for $\alpha = 0.05$, $k = 6$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Chemical Data

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches B, C, E, F, and G)	t-1=5	259.2	51.8	2.71 *	as compared to $F_{(tab.)} = 2.62$ for $\alpha = 0.05$, numerator df = 5, and denominator df = 24
Error	t(r-1)=24	458.4	19.1		
Total	tr-1=29	717.6			

Table 12. Continued

Organism	Analysis[a]
Hard Clams (continued)	Step 4. Student-Newman-Keuls' Multiple-Range Test for Identifying Cause of Significant Difference in Selected Chemical Data

A. Ranking of Treatment Means ($\bar{x}$) From Lowest to Highest

(1)	(2)	(3)	(4)	(5)	(6)
Reference Sediment - 8.4	Dredged Material, Reach E - 8.7	Dredged Material, Reach G - 10.2	Dredged Material, Reach F - 10.5	Dredged Material, Reach B - 12.4	Dredged Material, Reach C - 17.1

B. Comparison of Mean for Reference Sediment with Means for Dredged Material

Comparison of Means	Difference Between Means	
(1) versus (6)	17.1 - 8.4 = 8.7 *,	as compared to LSD (least significant difference) = 8.5 for $\alpha = 0.05$; $s_{\bar{x}} = 1.95$, and K = 6
(1) versus (5)	12.4 - 8.4 = 4.0 ns,	as compared to LSD = 8.1 for $\alpha = 0.05$, $s_{\bar{x}} = 1.95$, and K = 5
(1) versus (4)	10.5 - 8.4 = 2.1 ns,	as compared to LSD = 7.6 for $\alpha = 0.05$, $s_{\bar{x}} = 1.95$, and K = 4
(1) versus (3)	10.2 - 8.4 = 1.8 ns,	as compared to LSD = 6.9 for $\alpha = 0.05$, $s_{\bar{x}} = 1.95$, and K = 3
(1) versus (2)	8.7 - 8.4 = 0.3 ns,	as compared to LSD = 5.7 for $\alpha = 0.05$, $s_{\bar{x}} = 1.95$, and K = 2

Table 12. Continued

Organism	Analysis[a]

Sandworms

Step 1. Concentration of Chemicals in Tissue

Treatment (t): Replicate (r)	Reference (Disposal-Site) Sediment	Concentration (µg/g wet wt.) Dredged Material Reach A	Reach B	Reach C	Reach D	Reach E	Reach F	Reach G
1	15.0	17.5	6.8	4.4	5.5	4.7	18.3	10.1
2	7.8	4.0	3.0	9.8	6.5	3.9	22.8	11.1
3	9.4	4.2	5.4	3.2	5.2	12.2	35.5	6.3
4	7.5	10.8	1.2	6.0	5.4	13.2	12.7	12.5
5	12.0	4.9	6.0	4.0	7.1	14.5	10.7	14.8
Mean ($\bar{x}$):	10.3	8.3	4.5	5.5	5.9	9.7	20.0	11.0

Step 2. Cochran's Test for Homogeneity of Variances of Selected Chemical Data

Treatment (t)	Data (µg/g wet wt.) Mean ($\bar{x}$)	Variance (s^2)
Reference (Disposal-Site) Sediment	10.3	10.0
Dredged Material - Reach F	20.0	97.7
Dredged Material - Reach G	11.0	9.9

$$C_{(cal.)} = \frac{s^2(max.)}{\Sigma s^2} = \frac{97.7}{117.6} = 0.83\ *,$$

as compared to: $C_{(tab.)} = 0.75$ for $\alpha = 0.05$, $k = 3$, and $v = 4$

Step 3. Parametric One-Way Analysis of Variance (ANOVA) of Selected Chemical Data (Transformed Data)

Source of Variation	df	Sum of Squares	Mean Square	$F_{(cal.)}$	
Treatment (Reference Sediment; Dredged Material - Reaches F and G)	t-1=2	0.98	0.49	4.08 *,	as compared to $F_{(tab.)} = 3.89$ for $\alpha = 0.05$, numerator df = 2, and denominator df = 12
Error	t(r-1)=12	1.44	0.12		
Total	tr-1=14	2.42			

Table 12. Continued

Organism	Analysis[a]
Sandworms (continued)	Step 4. Student-Newman-Keuls' Multiple-Range Test for Identifying Cause of Significant Difference in Selected Chemical Data

A. Ranking of Treatment Means ($\bar{x}$) From Lowest to Highest

(1)	(2)	(3)
Reference Sediment - 2.40	Dredged Material, Reach G - 2.45	Dredged Material, Reach F - 2.96

B. Comparison of Mean for Reference Sediment with Means for Dredged Material

Comparison of Means	Difference Between Means	
(1) versus (3)	2.96 - 2.40 = 0.56 ns,	as compared to LSD (least significant difference) = 0.57 for $\alpha = 0.05$; $s_{\bar{x}} = 0.15$, and K = 3
(1) versus (2)	2.45 - 2.40 = 0.05 ns,	as compared to LSD = 0.46 for $\alpha = 0.05$, $s_{\bar{x}} = 0.15$, and K = 2

the preliminary ANOVA identified a similar statistically significant uptake of petroleum hydrocarbons from dredged material from Reaches F and G to sandworms, the significance of the uptake was not confirmed by Student-Newman-Keuls' test (Table 12).

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APPENDIX A

LABORATORY PROCEDURES FOR PREPARING DREDGED MATERIAL AND CONDUCTING BIOASSAYS[a]

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure		
		Aquatic Toxicologist	Laboratory Director	Division Director
1. Store control sediment (CS), reference sediment (RS), and 7 samples of dredged sediment (DS) at 2-4°C in separate containers. Mix sediment in each container as thoroughly as possible.	CS 3/10/81	Robert R. Boyer	Timothy J. Ward	
	RS 3/9/81	"	"	"
	DS 3/9/81	"	"	"
Solid Phase Bioassays				
Bioassays should be initiated by March 21, 1981 (2 weeks after March 7, 1981, earliest date of sediment collection). Do not be concerned with sophisticated photoperiod. Maintain dissolved oxygen in aquaria at >4 ppm. Cover aquaria to prevent salinity changes.				
2. Remove CS and RS from storage and wet sieve through 1-mm mesh into separate containers. Use minimum volume of artificial sea water [ASW] of salinity 30 ppt for sieving purposes. Place nonliving material remaining on sieve in appropriate containers.	3/11	"	"	"
3. Mix CS and RS in respective containers and allow to settle for 6 hr.	3/11	"	"	"
4. Decant ASW and mix CS and RS as thoroughly as possible.	3/11	"	"	"
5. Assign treatments (CS, RS, 7 samples of DS) and replicates (5 r per treatment) to aquaria.	3/11	"	"	"
6. Randomly position aquaria (45) in environmental chamber maintained at 20±1°C.	3/11	"	"	"

[a]This document is a copy of the work sheet that was used during the evaluation. The document differs from the work sheet in that dates appear in typed form and certifications were added at a single time after the dates were typed.

Laboratory Procedures (Continued)

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure		
		Aquatic Toxicologist	Laboratory Director	Division Director
7. Partially fill aquaria with ASW.	3/11	"	"	"
8. Place 30 mm of CS in 5 control aquaria. Place 30 mm of RS in each remaining aquarium. Fill 1st aquarium to ~10 mm, then 2nd aquarium to ~10 mm, ..., and finally last aquarium to ~10 mm. Repeat sequence until aquaria are filled to ~20 mm. Repeat sequence again until aquaria are filled to ~30 mm. This procedure will help to ensure that CS and RS in all aquaria are homogeneous. Store remaining CS and RS at 2-4°C for later use.	3/11	"	"	"
9. Replace ASW 1 hr after CS and RS have been added to aquaria. Do not disturb sediment during replacement.	3/11	"	"	"
10. Select 900 hard clams from holding tanks and randomly distribute into 45 culture dishes. Follow same procedure for sandworms.	3/11	"	"	"
11. Randomly distribute contents of culture dishes into aquaria.	3/11	"	"	"
12. If necessary, replace 75% of ASW 24 hr after animals are introduced into aquaria.	Not necessary	"	"	"
13. Acclimate animals for 48 hr. During this time period, remove dead animals and replace with live animals.	3/11-3/13	"	"	"

Laboratory Procedures (Continued)

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure		
		Aquatic Toxicologist	Laboratory Director	Division Director
14. During acclimation period, remove appropriate volumes of 7 samples of DS from storage and wet-sieve each sample through 1-mm mesh into separate containers. Use minimum volume of ASW for sieving purposes. Place nonliving material remaining on sieves in containers.	3/13	"	"	"
15. Mix 7 samples of DS in respective containers and allow to settle for 6 hr.	3/13	"	"	"
16. Decant ASW and mix 7 samples of DS as thoroughly as possible.	3/13	"	"	"
17. Place 15 mm of appropriate sample of DS in all but control and reference aquaria. Employ basic strategy identified in Step 8.	3/13	"	"	"
18. Remove remaining CS and RS from storage. Warm to test temperature (20±1°C). Add 15 mm of CS to each control aquarium and 15 mm of RS to each reference aquarium. Employ basic strategy identified in Step 8.	3/13	"	"	"
19. Replace 75% of ASW 1 hr after addition of 7 samples of DS and final addition of CS and RS.	3/13	"	"	"
20. Select 900 grass shrimp from holding tank and randomly distribute into 45 culture dishes.	3/13	"	"	"

Laboratory Procedures (Continued)

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Laboratory Director	Division Director
21. Randomly distribute contents of culture dishes into aquaria.	3/13	"	"	"
22. Perform the following activities:				
Every day after introduction of grass shrimp into aquaria				
• Record salinity, temperature, dissolved oxygen, and pH in each aquarium (record in log book) • Record obvious mortality, formation of tubes or burrows, and unusual behavior patterns of animals (record in log book)	Day 0 3/13	"	"	"
	Day 1 3/14	"	"	"
	Day 2 3/15	"	"	"
	Day 3 3/16	"	"	"
	Day 4 3/17	"	"	"
	Day 5 3/18	"	"	"
	Day 6 3/19	"	"	"
	Day 7 3/20	"	"	"
	Day 8 3/21	"	"	"
	Day 9 3/22	"	"	"
	Day 10 3/23	"	"	"
Every 2 days after introduction of grass shrimp into aquaria				
• Replace 75% of ASW	Day 2 3/15	"	"	"
	Day 4 3/17	"	"	"
	Day 6 3/19	"	"	"
	Day 8 3/21	"	"	"
23. At end of 10-day testing period, sieve sediment in each aquarium through 0.5-mm screen. Count live animals. Note sublethal responses. Depurate surviving organisms in ASW for 48 hr and preserve for bioaccumulation study.	3/23	"	"	"

Laboratory Procedures (Continued)

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Laboratory Director	Division Director
Suspended Particulate Phase Bioassays				
Bioassays should be initiated by March 21, 1981 (2 weeks after March 7, 1981, earliest date of dredged-sediment collection). Maintain 14-hr light photoperiod with cool-white fluorescent bulbs mounted approximately 0.5-1 m above tops of aquaria. Maintain dissolved oxygen in aquaria at >4 ppm. Cover aquaria to prevent salinity changes.				
24. Prepare 7 suspended-particulate-phase samples. Follow procedures in Appendix B of EPA/COE Implementation Manual. In particular:				
• Clean laboratory glassware thoroughly	3/11-3/19	"	"	"
• Remove from storage appropriate volumes of 7 samples of DS. Mix each sample as thoroughly as possible. Combine with ASW in 1:4 ratio by volume. Shake on automatic shaker for 30 min at 100 oscillations/min. Do not allow dissolved oxygen to reach zero. Settle for 1 hr. Collect supernatant.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"
25. Begin suspended-particulate-phase bioassays as soon as sufficient suspended particulate phase is prepared. Store initial volumes of suspended particulate phase at 2-4°C. Combine all volumes prior to use in bioassays.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"
26. For each species tested (copepod, mysid shrimp, and Atlantic silverside), assign treatments (culture-water control [100% ASW]; 10%, 50%, 100% suspended-particulate phase of each sample of DS) and replicates (3 r per treatment) to aquaria/culture dishes.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"

Laboratory Procedures (Continued)

Procedure		Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Laboratory Director	Division Director
27. For each species tested, randomly position aquaria/culture dishes in environmental chamber maintained at 20+1°C.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
28. Establish appropriate concentrations of control water and suspended particulate phase of each sample of DS in aquaria/culture dishes.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
29. Randomly distribute 10 individuals of test species into each aquarium/culture dish. Cover aquaria/dishes.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
30. Monitor the following variables:					
At start and end of 96-hr testing period					
• Salinity, temperature, dissolved oxygen, and pH in each aquarium/culture dish (record in log book).	Start of test (0 hr)	Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
	End of test (96 hr)	Copepod 3/20-3/21	"	"	"
		Mysid shrimp 3/16-3/24	"	"	"
		Silverside 3/16-3/24	"	"	"
During 96-hr testing period					
• Survival (record in log book)	Start of test (0 hr)	X	"	"	"
	4 hr	X	"	"	"
	8 hr	X	"	"	"
	24 hr	X	"	"	"
	48 hr	X	"	"	"
	72 hr	X	"	"	"
	End of test (96 hr)	X	"	"	"

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Laboratory Director	Division Director
Liquid Phase Bioassays				
Bioassays should be initiated by March 21, 1981 (2 weeks after March 7, 1981, earliest date of dredged-sediment collection). Maintain 14-hr light photoperiod with cool-white fluorescent bulbs mounted approximately 0.5-1 m above tops of aquaria. Maintain dissolved oxygen in aquaria at >4 ppm. Cover aquaria to prevent salinity changes.				
31. Prepare 7 liquid-phase samples. Follow procedures in Appendix B of EPA/COE Implementation Manual. In particular:				
• Clean laboratory glassware, filtration equipment, and filters (0.45 µ).	3/11-3/19	"	"	"
• Remove from storage appropriate volumes of 7 samples of DS. Mix each sample as thoroughly as possible. Combine with ASW in 1:4 ratio by volume. Shake on automatic shaker for 30 min at 100 oscillations/min. Do not allow dissolved oxygen to reach zero. Settle for 1 hr. Collect supernatant and filter (centrifugation may be employed if needed to expedite filtration process). Discard first 50 ml of filtrate passed through each filter. Collect remainder of filtrate.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"
32. Begin liquid phase bioassays as soon as sufficient liquid phase is prepared. Store initial volumes of liquid phase at 2-4°C. Combine all volumes prior to use in bioassays.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"
33. For each species tested (copepod, mysid shrimp, and Atlantic silverside), assign treatments (culture-water control [100% ASW]; 10%, 50%, 100% liquid phase of DS) and replicates (3 r per treatment) to aquaria/culture dishes.	Copepod 3/16-3/17	"	"	"
	Mysid shrimp 3/12-3/20	"	"	"
	Silverside 3/12-3/20	"	"	"

Laboratory Procedures (Continued)

Procedure		Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Laboratory Director	Division Director
34. For each species tested, randomly position aquaria/culture dishes in environmental chamber maintained at 20±1°C.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
35. Establish appropriate concentrations of control water and liquid phase of each sample of DS in aquaria/culture dishes.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
36. Randomly distribute 10 individuals of test species into each aquarium/culture dish. Cover aquaria/dishes.		Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
37. Monitor the following variables:					
At start and end of 96-hr testing period					
• Salinity, temperature, dissolved oxygen, and pH in each aquarium/culture dish (record in log book.	Start of test (0 hr)	Copepod 3/16-3/17	"	"	"
		Mysid shrimp 3/12-3/20	"	"	"
		Silverside 3/12-3/20	"	"	"
	End of test (96 hr)	Copepod 3/20-3/21	"	"	"
		Mysid shrimp 3/16-3/24	"	"	"
		Silverside 3/16-3/24	"	"	"
During 96-hr testing period					
• Survival (record in log book)	Start of test (0 hr)	X	"	"	"
	4 hr	X	"	"	"
	8 hr	X	"	"	"
	24 hr	X	"	"	"
	48 hr	X	"	"	"
	72 hr	X	"	"	"
	End of test (96 hr)	X	"	"	"

B.1 Liquid Phase Bioassays

Table B1. Results of liquid phase bioassays with copepods, *Acartia tonsa*[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	9
	3	10	10	10	9	9	9	9
	Mean ($\bar{x}$):							9.33 (93.3%)
10% liquid phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	9	8	7	7
	3	10	10	10	9	8	8	7
Dredged material - Reach B	1	10	10	10	9	9	8	8
	2	10	10	10	10	10	9	8
	3	10	10	10	9	9	8	8
Dredged material - Reach C	1	10	10	10	10	10	8	8
	2	10	10	10	10	10	9	8
	3	10	10	10	10	10	9	8
Dredged material - Reach D	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	9	8
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	9	8	8	8
	3	10	10	10	10	10	10	9
Dredged material - Reach F	1	10	10	10	10	10	7	7
	2	10	10	10	10	10	9	8
	3	10	10	10	10	9	8	8
Dredged material - Reach G	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10

Table B1. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% liquid phase								
Dredged material - Reach A	1	10	10	10	8	7	6	6
	2	10	10	10	10	10	10	10
	3	10	10	10	9	8	7	5
Dredged material - Reach B	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	9	8
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	9	9	9
	2	10	10	10	10	9	7	7
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	8	8	8	7
	2	10	10	10	9	9	7	6
	3	10	10	10	10	9	9	9
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	9	9	9	9
	2	10	10	10	10	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	8	8
	3	10	10	10	10	10	9	8
100% liquid phase								
Dredged material - Reach A	1	10	10	10	9	5	2	0
	2	10	10	10	10	5	4	4
	3	10	10	10	10	5	3	2
	Mean ($\bar{x}$):							2.00 (20.0%)
Dredged material - Reach B	1	10	10	10	9	8	6	6
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	7	6
	Mean ($\bar{x}$):							7.00 (70.0%)

Table B1. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	10	8	6
	2	10	10	10	9	9	9	9
	3	10	10	10	9	9	7	6
	Mean ($\bar{x}$):							7.00 (70.0%)
Dredged material - Reach D	1	10	10	10	9	9	8	8
	2	10	10	10	10	9	8	8
	3	10	10	10	9	9	9	9
	Mean ($\bar{x}$):							8.33 (83.3%)
Dredged material - Reach E	1	10	10	10	10	10	10	9
	2	10	10	10	10	9	9	9
	3	10	10	10	10	9	8	8
	Mean ($\bar{x}$):							8.67 (86.7%)
Dredged material - Reach F	1	10	10	10	9	9	8	8
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.00 (90.0%)
Dredged material - Reach G	1	10	10	10	8	7	6	5
	2	10	10	10	9	8	7	7
	3	10	10	10	10	8	7	7
	Mean ($\bar{x}$):							6.33 (63.3%)

[a]Bioassays were conducted at 20±1°C in 100-ml culture dishes. A 14-hr light (~1200 $\mu w/cm^2$ at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 5.8-8.0 mg/l at the start of the bioassays to 6.9-7.4 mg/l at the end of the tests. pH varied from 7.7-8.0 (start of bioassays) to 7.4-7.9 (end of bioassays). Salinity was maintained at 30 ppt.

Table B2. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% liquid phase								
Dredged material - Reach A	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
100% liquid phase								
Dredged material - Reach A	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	9
	Mean ($\bar{x}$):							9.67 (96.7%)

Table B2. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach D	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	9
	Mean ($\bar{x}$):							9.33 (93.3%)
Dredged material - Reach E	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach G	1	10	10	10	10	10	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)

[a]Bioassays were conducted at 20±1°C in 1000-ml culture dishes. Animals were fed live 48-hr-old Artemia (brine shrimp) nauplii at a rate of ~1 ml of culture/dish/day. A 14-hr light (~1200 µw/cm^2 at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 6.8-8.7 mg/l at the start of the bioassays to 6.5-7.7 mg/l at the end of the tests. pH varied from 7.7-8.0 (start of bioassays) to 7.6-7.9 (end of bioassays). Salinity was maintained at 30 ppt.

Table B2. Results of liquid phase bioassays with mysid shrimp, *Neomysis americana*[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
10% liquid phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10

B.2 Suspended Particulate Phase Bioassays

Table B3. Results of liquid phase bioassays with Atlantic silversides, Menidia menidia[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
10% liquid phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	9
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	9	9	9
	3	10	10	10	9	9	9	9
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	9	9	9	9

Table B3. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach E	1	10	10	10	9	9	9	9
	2	10	10	10	8	6	6	6
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							8.33 (83.3%)
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)

[a]Bioassays were conducted at 20±1°C in 19-liter aquaria. A 14-hr light (~1200 µw/cm^2 at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 6.7-8.2 mg/l at the start of the bioassays to 4.3-7.3 mg/l at the end of the tests. pH varied from 7.5-8.0 (start of bioassays) to 7.3-7.9 (end of bioassays). Salinity was maintained at 30 ppt.

Table B3. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% liquid phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	9	9
	3	10	10	10	10	9	9	9
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	9	9	9	9
100% liquid phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	8	8	8	8
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.33 (93.3%)

Table B4. Results of suspended particulate phase bioassays with copepods, Acartia tonsa[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	9
	3	10	10	10	9	9	9	9
	Mean ($\bar{x}$):							9.33 (93.3%)
10% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	9
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	10	9	9
	2	10	10	10	10	10	10	8
	3	10	10	10	10	10	9	9
Dredged material - Reach D	1	10	10	10	10	9	9	8
	2	10	10	10	9	9	9	9
	3	10	10	10	10	9	8	7
Dredged material - Reach E	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	9	9
Dredged material - Reach F	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	9	9
Dredged material - Reach G	1	10	10	10	9	9	9	9
	2	10	10	10	10	9	9	8
	3	10	10	10	10	10	10	10

Table B4. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	9	9
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	8	8
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	9	9
	3	10	10	10	10	10	9	9
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	9	9	9
Dredged material - Reach D	1	10	10	10	10	10	9	9
	2	10	10	10	10	9	9	9
	3	10	10	10	9	9	9	8
Dredged material - Reach E	1	10	10	10	10	8	7	7
	2	10	10	10	8	8	8	8
	3	10	10	10	10	7	7	7
Dredged material - Reach F	1	10	10	10	10	9	8	8
	2	10	10	10	10	10	10	9
	3	10	10	10	10	9	9	9
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	9
100% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	8	6
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							8.33 (83.3%)
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)

Table B4. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	9	9	8	6
	Mean ($\bar{x}$):							8.33 (83.3%)
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	8
	3	10	10	10	10	9	9	9
	Mean ($\bar{x}$):							9.00 (90.0%)
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach F	1	10	10	10	10	9	9	8
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	9
	Mean ($\bar{x}$):							9.00 (90.0%)
Dredged material - Reach G	1	10	10	10	10	10	9	8
	2	10	10	10	10	10	9	9
	3	10	10	10	9	9	8	8
	Mean ($\bar{x}$):							8.33 (83.3%)

[a]Bioassays were conducted at 20±1°C in 100-ml culture dishes. A 14-hr light (~1200 µw/cm^2 at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 4.3-8.0 mg/l at the start of the bioassays to 7.0-7.5 mg/l at the end of the tests. pH varied from 7.7-8.0 (start of bioassays) to 7.5-7.9 (end of bioassays). Salinity was maintained at 30 ppt.

Table B5. Results of suspended particulate phase bioassays with mysid shrimp, Neomysis americana[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
10% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	9
	3	10	10	10	10	10	10	10
Dredged material - Reach B	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	9	9	9
Dredged material - Reach C	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	10	10	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10

Table B5. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	9
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
100% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	10	8
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.33 (93.3%)
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)

Table B5. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach F	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)

[a]Bioassays were conducted at 20±1°C in 1000-ml culture dishes. Animals were fed live 48-hr-old Artemia (brine shrimp) nauplii at a rate of ~1 ml of culture/dish/day. A 14-hr light (~1200 µw/cm^2 at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 7.1-8.7 mg/l at the start of the bioassays to 6.4-7.8 mg/l at the end of the tests. pH varied from 7.7-8.0 (start of bioassays) to 7.5-7.8 (end of bioassays). Salinity was maintained at 30 ppt.

Table B6. Results of suspended particulate phase bioassays with Atlantic silversides, Menidia menidia[a]

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Culture water control (worst-case)	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
10% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	8	7	7	7
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	9
	3	10	10	10	8	8	8	8
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10

Table B6. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
50% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach C	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach D	1	10	10	10	10	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	10
Dredged material - Reach F	1	10	10	10	9	8	7	7
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
Dredged material - Reach G	1	10	10	10	10	10	10	10
	2	10	10	10	9	9	9	9
	3	10	10	10	10	10	10	10
100% suspended particulate phase								
Dredged material - Reach A	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	8	8	8	8
	Mean ($\bar{x}$):							9.00 (90.0%)
Dredged material - Reach B	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	8	8	8	8
	Mean ($\bar{x}$):							9.33 (93.3%)

Table B6. Continued

Treatment (Exposure Condition)	Replicate (r)	Number of Survivors						
		0 hr	4 hr	8 hr	24 hr	48 hr	72 hr	96 hr
Dredged material - Reach C	1	10	10	10	10	10	10	10
	2	10	10	10	10	9	9	9
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach D	1	10	10	10	9	9	9	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.67 (96.7%)
Dredged material - Reach E	1	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							10.00 (100.0%)
Dredged material - Reach F	1	10	10	10	10	10	10	9
	2	10	10	10	10	10	10	10
	3	10	10	10	10	10	9	9
	Mean ($\bar{x}$):							9.33 (93.3%)
Dredged material - Reach G	1	10	10	10	9	9	9	9
	2	10	10	10	8	8	8	8
	3	10	10	10	10	10	10	10
	Mean ($\bar{x}$):							9.00 (90.0%)

[a]Bioassays were conducted at 20±1°C in 19-liter aquaria. A 14-hr light (~1200 µw/cm^2 at surface of dishes) and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Test media were not aerated. Dissolved oxygen concentrations in the media ranged from 7.2-8.2 mg/l at the start of the bioassays to 4.2-6.0 mg/l at the end of the tests. pH varied from 7.5-8.0 (start of bioassays) to 7.4-7.7 (end of bioassays). Salinity was maintained at 30 ppt.

B.3 Solid Phase Bioassays

Table B7. Results of solid phase bioassays with grass shrimp (Palaemonetes pugio), hard clams (Mercenaria mercenaria), and sandworms (Nereis virens)[a]

Treatment (t)	Replicate (r)	Number of Survivors[b,c]			
		Grass Shrimp	Hard Clams	Sand-worms	Total
Control (Culture) Sediment	1	20	19	20	59
	2	20	20	17	57
	3	20	20	20	60
	4	20	20	19	59
	5	20	20	20	60
	Mean ($\bar{x}$):	20.00	19.80	19.20	59.00
	(%):	(100.0)	(99.0)	(96.0)	(98.3)
Reference (Disposal-Site) Sediment	1	20	20	17	57
	2	20	19	19	58
	3	20	19	18	57
	4	20	20	18	58
	5	18	19	15	52
	Mean ($\bar{x}$):	19.60	19.40	17.40	56.40
	(%):	(98.0)	(97.0)	(87.0)	(94.0)
Dredged Material - Reach A	1	19	19	16	54
	2	20	20	20	60
	3	20	20	15	55
	4	20	20	5	45
	5	20	20	19	59
	Mean ($\bar{x}$):	19.80	19.80	15.00	54.60
	(%):	(99.0)	(99.0)	(75.0)	(91.0)
Dredged Material - Reach B	1	20	19	16	55
	2	20	19	18	57
	3	20	20	18	58
	4	20	20	16	56
	5	19	18	15	52
	Mean ($\bar{x}$):	19.80	19.20	16.60	55.60
	(%):	(99.0)	(96.0)	(83.0)	(92.7)

Table B7. Continued

Treatment (t)	Replicate (r)	Number of Survivors[b,c] Grass Shrimp	Hard Clams	Sand-worms	Total
Dredged Material - Reach C	1	20	20	17	57
	2	20	20	16	56
	3	20	20	20	60
	4	20	20	19	59
	5	19	20	17	56
	Mean ($\bar{x}$):	19.80	20.00	17.80	57.60
	(%):	(99.0)	(100.0)	(89.0)	(96.0)
Dredged Material - Reach D	1	20	20	18	58
	2	20	19	19	58
	3	20	20	17	57
	4	20	20	17	57
	5	20	20	12	52
	Mean ($\bar{x}$):	20.00	19.80	16.60	56.40
	(%):	(100.0)	(99.0)	(83.0)	(94.0)
Dredged Material - Reach E	1	19	20	18	57
	2	20	20	13	53
	3	20	20	18	58
	4	20	20	15	55
	5	20	20	20	60
	Mean ($\bar{x}$):	19.80	20.00	16.80	56.60
	(%):	(99.0)	(100.0)	(84.0)	(94.3)
Dredged Material - Reach F	1	20	20	17	57
	2	19	20	17	56
	3	20	20	18	58
	4	20	20	19	59
	5	19	19	19	57
	Mean ($\bar{x}$):	19.60	19.80	18.00	57.40
	(%):	(98.0)	(99.0)	(90.0)	(95.7)

Table B7. Continued

Treatment (t)	Replicate (r)	Number of Survivors[b,c]			
		Grass Shrimp	Hard Clams	Sand-worms	Total
Dredged Material - Reach G	1	17	20	17	54
	2	20	19	19	58
	3	19	20	17	56
	4	20	18	17	55
	5	20	20	18	58
	Mean ($\bar{x}$):	19.20	19.40	17.60	56.20
	(%):	(96.0)	(97.0)	(88.0)	(93.7)

[a]Bioassays (10-day tests) were conducted at 20±1°C in 38-liter aquaria. Organisms were exposed to each replicate of a treatment in a single aquarium. Water in aquaria was exchanged by the replacement, as compared to the flow-through, method and was aerated. A 14-hour light and 10-hr dark photoperiod was maintained with cool-white fluorescent bulbs. Minimum values of dissolved oxygen and pH recorded during the bioassays were 4.8 mg/l and 7.2, respectively. Salinity was maintained at 30 ppt.

[b]Twenty (20) individuals of each species were initially exposed to each replicate of a treatment. Thus, a total of 60 animals was employed in each aquarium.

[c]In addition to monitoring survival of all species, burrowing behavior of sandworms was noted at 2-day intervals. No differences were observed among aquaria.